Some Aspects of Spatfall of the New Zealand Rock Oyster During 1974

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(4 Text figures)

INTRODUCTION

Mahurangi estuary in New Zealand (Lat. 38°30′S; Long. 174°43′E) is an important spat source of the New Zealand rock oyster, *Saccostrea glomerata* (Gould, 1850) [= *Crassostrea glomerata* (Gould, 1850)], being the only area where commercial-scale spatfall had been consistently recorded. Commercial seed collection began in 1968, and Curtin (1971, 1973) has provided spat collection records from 1970 through 1972. Spatfall usually begins early in January and extends into April, with one or two peak settlements occurring around February. The larvae settle in the intertidal region through a 1 m vertical range about mean low water level (personal observation). Collectors are usually set out at MLWN about the end of December, and are removed to growing areas at the end of April.

The spatting area in Mahurangi is less than 5 ha and catches fluctuate. For these reasons methods of increasing production are being investigated: one method is to time the setting out of collectors and the handling so as to get abundant catches of spat and to avoid heavy settlement of fouling organisms that interfere with survival and growth of spat.

The summer of 1974 was a successful breeding season which made it possible to study the precise seasonal history of spatfall, patterns of settlement on collectors and other practical problems and procedures in seed collection that are not well understood. The results of these studies are presented and discussed in this paper.

MATERIALS AND METHODS

Commercial spat collectors were used for all observations for monitoring spat settlement. A standard collector (Figure 1) consists of 30 fibrolite (asbestos-cement) slats, each 120×5×0.6 cm, arranged in a bundle of 10 layers and 3 columns, with 5 cm between the columns; each layer is separated by 2 wooden spacers, about 12 mm thick. Collectors were set out in racks in Huawai Bay in the Mahurangi estuary in the middle of January, and every 4 weeks thereafter 1 collector was examined. A set of collectors was exposed to monitor spatfall between middle of December 1973 and mid-January 1974.

For analysis, 1 slat was taken from each layer (usually a slat from the middle column) and the total number of spat was counted on its upper and lower surface, and their sizes measured. The size of the spat refers to its greatest width (Thompson, 1968) measured in mm. Where spat density was very high, it was necessary to restrict counting and measuring to one-half of each slat, particularly of the lower surface. In some collectors, with uneven spat distribution, one more slat was examined from each layer to obtain a better estimate of the number of spat/slat. These collectors, examined at 4-weekly intervals gave cumulative spat counts (less mortality) for the period January through May 1974.

We also made tests to determine the effects of spat collector manipulations practised by some farmers. For example, it is well known that rock oyster settlement is heavier on lower than on upper horizontal surfaces of

Fisheries Research Publication No. 288

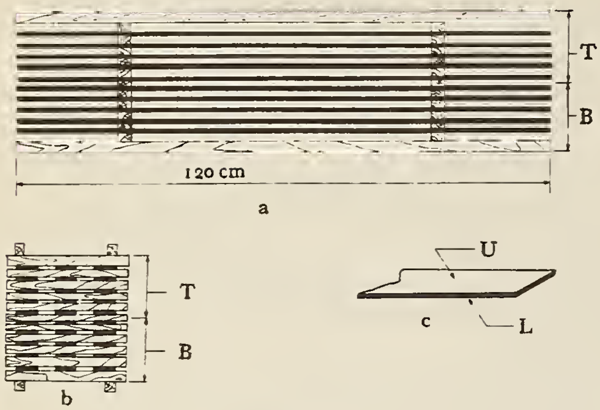

Figure 1

Arrangement of slats, (a) side view, (b) end view, in a commercial bundle of spat collector; T: top half and B: bottom half of bundle; (c) portion of slat, with U: upper, and L: lower surface

the slats, and some farmers overturn their collectors halfway through the spatfall season in the hope of securing an even distribution of spat on both sides of the slat. Our tests were made at the same site and began in February: every month one experimental collector was overturned and at the end of the spatfall season the spat distribution on these collectors was compared with normally handled collectors.

Some farmers raise the level of their collectors after the peak spatfall season hoping thereby to avoid settlement of competitive organisms like mussels and thus improve spat survival. We tested this by shifting one collector in February, March and April from the rack where it received its catch of spat to another rack at the same site that was 30 cm higher. At the end of the season spat counts were made on test collectors and compared with counts on collectors that were normally handled.

The results observed have been presented in four ways: for each period of cultch exposure, 1) the total count of spat per each collector has been estimated, 2) size frequency distributions (in 5 mm groups) of spat within the collector have been analysed, 3) counts of spat settlement on upper and lower surfaces have been presented separately to show preferences, and 4) the slats in each collector have been grouped according to whether they came from the top or bottom 5 layers of the collector (see Figure 1). The terms "upper" and "lower" (within quotation marks) surfaces in the following description refer to new orientations, consequent on collectors being overturned through 180°, but which actually represent the original lower and upper surfaces respectively.

OBSERVATIONS

Monitoring collectors exposed from mid-December to mid-January (4 weeks) showed sparse settlement (approximately 3 spat/slat of sizes 1 to 1.5 mm), and it is therefore probable that no successful spawning or settlement occurred during this period. Most of the seasonal settlement took place after 15 January and Table 1 shows results of spat settlement on experimental collectors that were exposed for approximately 1, 2, 3 and 4 months from mid-January to mid-May 1974. Since collectors were examined only about the middle of each month, precise times of spatfall could not be determined simply from counts of spat. However when considered with size-frequency distribution (Figure 2), and what is known

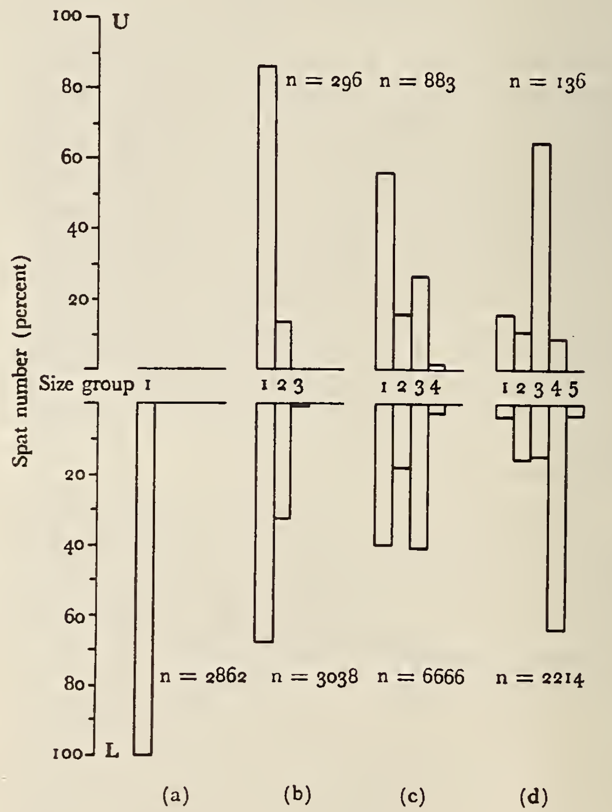

Figure 2

Size distribution and number of spat on collectors set at the normal level (MLWN) on 19 January 1974, and examined at monthly intervals in (a) February, (b) March, (c) April and (d) May. Spat settled on upper (U) and lower (L) surfaces are shown separately. Size groups: 1 = < 5 mm, 2 = 5 - 10 mm, 3 = 10 - 15 mm, 4 = 15 - 20 mm, 5 = > 20 mm about spat growth (normal growth rate is nearly 1 mm per week during the summer months – own unpublished data) it is obvious that settlement had been spread out through the 1974 season, with a fairly heavy set in February and again another set after the middle of March.

A mean settlement rate of 255 spat/slat was recorded on 19 February when the first collectors were examined (Table 1). The spat averaged 2 mm in width suggesting that the first commercial settlement probably began at the end of January/early February. Apparently no heavy spatfalls occurred between February and the middle of March, because collectors examined on 18 March indicate a reduction in number of spat from 255 to 238/slat (Table 1), perhaps from natural mortality, and only 12.9% of these were < 2 mm wide (Figure 2). However, in the next period, from mid-March to mid-April, there is a marked increase to 417 spat/slat, and nearly 30% of these spat were < 2 mm in size, obviously the result of a heavy spatfall during this period. During the second spatfall of the season, the settlement was also heavy in the top half of the collectors. This brought about an increase in the top/bottom ratio of spat from 0.67 for 18 March to 1.09 on 17 April (Table 1). This shows an increase from 37% to 57% of the total number of the spat settling on the top layers of the collector.

Table 1

Density of spat settlement on normal collectors examined at monthly intervals, January through May 1974. Each collector of 30 slats has been split into two halves, T: top and B: bottom, of 5 layers and 15 slats each. The number of spat on upper (U) and lower (L) surface of each slat has been shown separately.

Period and Date examined	Portion of Collector	Surface	No. of slats examined	No. of spat measured	Mean No. of spat/ surface	Spat Density ($/cm^2$)	Total No. of spat on surfaces	% of Total	Total No. spat/ collector	Mean No. of spat/ slat	Mean spat density/ slat (cm^2)
Jan-Feb											
19 Feb	T	L	7	1083	154.7	0.269	2321	30.3			
	T	U	7	0	0		0				
	B	L	5	1779	355.8	0.619	5337	69.7			
	B	U	5	0	0		0				
	[1]								7658	255.3	0.222
Jan-March											
18 March	T[2]	L	7	1248	178.3	0.310	2674	37.4			
	T	U	7	93	13.3	0.023	200	2.8			
	B	L	7	1790	255.7	0.445	3836	53.7			
	B	U	7	203	29.0	0.050	435	6.1			
									7145	238	0.207
Jan-April											
17 April	T	L	10	3902	390.2	0.679	5853	46.7			
	T[3]	U	10	457	45.7	0.079	685	5.5			
	B	L	8	2764	345.5	0.601	5182	41.4			
	B	U	8	426	53.2	0.092	798	6.4			
									12519	417.3	0.363
Jan-May											
17 May	T	L	5	1258	251.6	0.437	3774	48.6			
	T	U	5	60	12	0.021	180	2.3			
	B[4]	L	4	956	239	0.416	3585	46.2			
	B	U	5	76	15.2	0.026	228	2.9			
									7767	258.9	0.225

[1]First spatfall.
[2]No spatfall.
[3]Second spatfall.
[4]Bottom slats heavily fouled.

SETTLEMENT PATTERNS IN EXPERIMENTAL COLLECTORS

(a) Overturned Collectors

On 19 February no spat were found on the upper surfaces of slats in collectors that had been exposed at the normal level for 4 weeks from 19 January. Consequently, when these collectors were overturned on 19 February, what then became their lower surfaces had probably no spat in them. All the spat subsequently recorded on these "lower" surfaces must therefore have settled after 19 February (Table 2). This is borne out by the fact that 61.1% of the spat on the "lower" surface were $<$5mm, and only 17% were $>$10mm (Figure 3). In the controls that were examined at the same time (Figure 2), only 3.2% were $<$5mm, and 81.1% were $>$10mm. Correspondingly, in experimental collectors, spat counts on "upper" surfaces actually represent settlement that took place on lower surfaces before collectors were overturned.

By the middle of March, spat had begun to settle naturally on the upper surfaces of slats as well, reaching a density of 0.036 spat/cm² (sizes $<$5mm) in normal collectors. The lower surfaces of these collectors showed a spat density of 0.377 spat/cm². Collectors that were overturned in March showed a higher spat density (0.136 spat/cm²) on "lower" surface but spat were mostly of sizes $<$5mm. The "upper" surfaces of overturned collectors showed densities of 0.390 spat /cm², and spat were

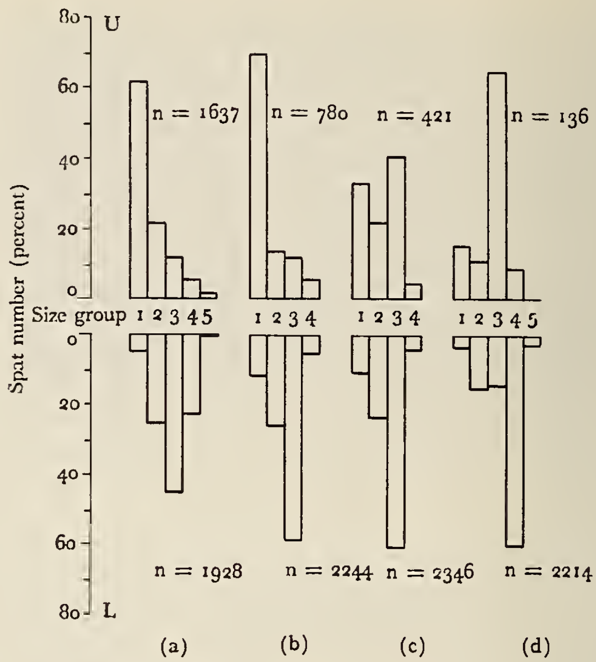

Figure 3

Size distribution and number of spat on upper and lower surfaces of experimental collectors which were overturned at monthly intervals in (a) February, (b) March and (c) April, compared with (d) a normal unturned bundle. All collector bundles removed from racks on 17 May 1974. Other legend as in Figure 1

Table 2

Density of spat settlement on experimental collectors that were overturned in February, March and April 1974. L' and U' refer to original lower and upper surfaces respectively, and therefore denote present U and L surfaces. Similarly T' and B' are original positions.

Date Re-oriented	Portion of Collector	Surface	No. of slats examined	No. of spat measured	Mean No. of spat/surface	Spat Density (/cm²)	Total No. of spat on surfaces	% of Total	Total No. spat/collector	Mean No. of spat/slat	Mean spat density/slat (cm²)
19 Feb	B'	L'	5	678	135.6	0.236	2034	19.0			
	B'	U'	5	729	145.8	0.254	2187	20.4			
	T'	L'	5	1250	250	0.435	3750	35.1			
	T'	U'	5	908	181.6	0.316	2724	25.5			
									10695	356.5	0.310
18 March	B'	L'	5	1196	239.2	0.416	3588	39.5			
	B'	U'	5	445	89	0.155	1335	14.7			
	T'	L'	5	1048	209.6	0.364	3144	34.6			
	T'	U'	5	335	67	0.116	1005	11.1			
									9072	302.4	0.263
17 April	B'	L'	5	1164	232.8	0.405	3492	42.1			
	B'	U'	5	158	31.6	0.055	474	5.7			
	T'	L'	5	1182	236.4	0.411	3546	42.7			
	T'	U'	5	263	52.6	0.091	789	9.5			
									8301	276.7	0.241

of larger size when compared to normal March collectors; however both spat modal size and densities (0.421 spat/cm²) were lower than corresponding surfaces of normal collectors examined in May (Figure 3).

(b) Collectors Raised to Higher Levels

In collectors that were raised 30 cm on 19 February, the overall spat density was 0.221/cm² of available surface, with 0.368 spat/cm² on lower surface and 0.074 spat /cm² on upper surface (Table 3). The overall spat density was thus very similar to those of normal (control) collectors, which had 0.225 spat/cm², though the distribution of spat was denser on lower surfaces (0.426 spat/cm²) and lighter on upper surfaces (0.023 spat/cm²) of normal collectors. When compared to overturned collectors of February, the raised collectors had slightly higher spat densities (+0.033/cm²) on lower surfaces but much lower densities (−0.211/cm²) on upper surfaces (cf. Tables 2 and 3). However, size frequency distributions (Figure 4) show marked differences on sizes of spat, especially on upper surfaces.

Collectors that were raised 30 cm in March showed an overall density of 0.231 spat/cm², a slight increase over those raised in February. The spat were also denser on lower (0.404/cm²) and lighter on upper (0.057/cm²) surfaces, but were of smaller size. A similar difference was observed when these experimental collectors were compared with normal collectors which had also a larger modal size of spat.

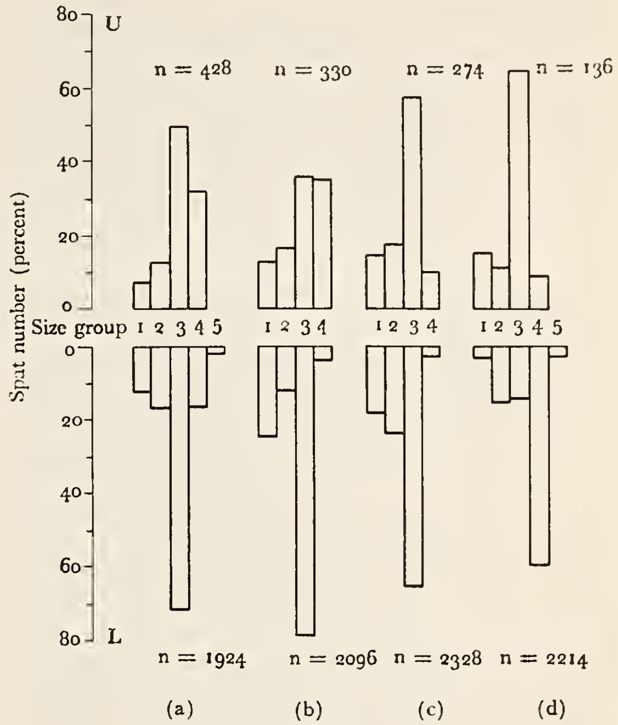

Figure 4

Size distribution and number of spat on upper and lower surfaces of experimental collectors which were raised 30 cm to a higher rack at monthly intervals in (a) February, (b) March and (c) April, compared with (d) a normal level bundle. All collector bundles removed from racks on 17 May 1974. Other legend as in Figure 1

Table 3

Density of spat settlement on experimental collectors that were raised 30 cm from normal level in February, March and April 1974. Legend as in Table 1.

Date Shifted	Portion of Collector	Surface	No. of slats examined	No. of spat measured	Mean No. of spat/ surface	Spat Density (/cm²)	Total No. spat on surfaces	% of Total	Total No. spat/ collector	Mean No. of spat/ slat	Mean spat density (/cm²)
19 Feb	T	L	5	1144	228.8	0.398	3432	44.9			
	T	U	5	172	34.4	0.060	516	6.7			
	B[1]	L	4	780	195	0.339	2925	38.3			
	B	U	5	256	51.2	0.089	768	10.1			
									7641	254.7	0.221
18 March	T	L	5	1186	237.2	0.412	3558	44.7			
	T	U	5	130	26	0.045	390	4.9			
	B	L	4	910	227.5	0.396	3412	42.9			
	B	U	5	200	40	0.069	600	7.5			
									7960	265.3	0.231
17 April	T	L	5	1166	233.2	0.388	3498	44.3			
	T	U	5	158	31.6	0.055	474	6.0			
	B	L	5	1162	232.4	0.404	3486	44.2			
	B	U	4	116	29	0.050	435	5.5			
									7893	263.1	0.229

[1]Bottom slats heavily fouled.

Collectors that were raised 30 cm in April were nearly identical to those raised in March as regards overall spat density (0.229/cm^2), as well as distribution on lower (0.405/cm^2) and upper (0.052/cm^2) surfaces. They were also similar to experimental collectors overturned in April as regards spat density and modal size. When compared to normal collectors (controls) spat size differences were observed, with bigger size spat in larger numbers in the control collectors (cf. Figures 2 and 4).

SETTLEMENT ON UPPER vs. LOWER SURFACES

In normal collectors placed on the racks on 19 January and examined on 19 February, the entire spat settlement was on the lower surfaces of slats; but in normal collectors examined towards the end of the spatting season (17 May) 5.25% of spat had settled on upper surfaces of slats. However, collectors examined on 17 April showed a slightly higher rate of settlement (11.86%) on upper surfaces as a result of a second spatfall but these spat had probably failed to survive. This is indicated by the reduction of spat densities on upper surfaces of slats, from 0.085/cm^2 in April to 0.023/cm^2 in May (Figure 2 and Table 1). Analyses of size frequencies reveal that smaller sized spat ($\sim$5 mm) were greatly reduced in numbers between April and May.

Spat distribution was different in collectors that were experimentally treated: those overturned early in the spatting season (February) had somewhat similar spat densities on both surfaces, 0.335/cm^2 on lower and 0.285/cm^2 on upper surfaces, but their size composition showed marked differences (Figure 3); smaller sized spat were predominant on upper surfaces, those $<$ 5 mm constituting 61.1% of the spat on the upper surface against 5% on the lower surface. Thereafter, the numbers that settled on upper surfaces of overturned collectors gradually decreased (Table 2 and Figure 3), so that at the end of the spatting season spat densities were similar to corresponding surfaces of normal collectors. In collectors that were raised to higher levels, spat distribution and densities did not vary greatly from month to month, but those shifted in February had slightly fewer spat on their lower surface. This was probably due to the fact that raising the level of the collectors early in the season had caused interruption of spat settlement, and failure of the spat to settle or survive at the new levels. However, spat settlement on upper surfaces of all raised collectors was more than double the density of normal level collectors.

SETTLEMENT PATTERNS WITHIN THE COLLECTOR

Initial settlement was predominantly in the bottom half of the collectors (Table 1), accounting for 69.7% of the spat counted on normal collectors in February; however, as the season progressed, the relative number of spat settling in the top half increased, from 40.2% on 18 March to 52.2% on 17 April and, at the end of the spatting season, spat numbers were nearly evenly distributed with 50.9% at the top and 49.1% in the bottom half. As a result of differences in spatfall times on the two halves of the collectors, size differences were noticed: thus in the bottom half spat were predominantly ($>$77%) of larger size (15 mm and above) and there were no spat smaller than 5 mm; in the top half nearly 30% of the spat were $<$10 mm and only 53% were $>$15 mm.

In experimental collectors (Tables 2 and 3) the same trends were seen, the degree of difference being related to the time at which the collectors were re-oriented. Thus collectors overturned in February showed greater spat density and settlement on slats which were originally in the top half, but small sized spat ($<$5 mm) occurred in greater number in the original bottom half of the collector. However, collectors overturned in March showed lesser spat density and settlement in the original top half, while collectors overturned in April showed slightly higher numbers in the same half. The percentage of small sized spat in the original bottom half of the collector was somewhat higher than in the layers of the top half in both March and April collectors. In collectors that were shifted to higher level in different months, top halves of collectors showed on each occasion higher percentage of spat, which were made of small sized spat ($<$10 mm) particularly in those shifted in March and April.

SETTLEMENT OF COMPETITIVE ORGANISMS

(a) Other Oysters

Spat of two other oyster species are sometimes found on collectors laid out for rock oysters (Dinamani, 1971). These were an unidentified flat oyster, *Ostrea* sp., and the Pacific oyster, *Crassostrea gigas* (Thunberg, 1793), which are somewhat difficult to distinguish from one another at early spat stages. Flat oyster spat were rare in 1974, only 8 - 10 spat/bundle were noted on 19 February, and none were found during the three subsequent monthly samplings. However, Pacific oyster spatfall was heavier than in previous seasons (DINAMANI, 1974b): Table 4 gives details of the Pacific oyster settlement on collector samples examined during the season. It may be observed that the Pacific oyster settled in densities of 96 spat/bundle of normally handled collectors, 70% of them being on the lower surfaces of slats. Maximum settlement (213 spat/bundle) was observed in collectors that were overturned on 19 February. The distribution of these spat indicates that most settled on lower surfaces of slats between 19 February and 18 March, just before and soon after the collectors were overturned: this is revealed by the fact that the settlement of the Pacific oysters gradually decreased through March and April, and also because collectors overturned in March and April caught more Pacific oyster spat than the normally handled collectors and by the fact that numbers of spat on upper and lower surfaces of overturned collectors in April were almost equal.

Table 4

Pacific oyster spat recorded on collectors examined on 17 May 1974.

Type of collector	No. of spat: upper surface	No. of spat: lower surface	Total spat /collector
1. Normal collector	27	69	96
2. Overturned collectors:			
Reoriented Feb.	74[1]	159[1]	213
Reoriented Mar.	36[1]	130[1]	166
Reoriented Apr.	66[1]	67[1]	133
3. Collectors raised 30 cm:			
Raised Feb.	42	55	97
Raised Mar.	24	50	74
Raised Apr.	28	36	64

[1]Refers to present upper and lower surface.

(b) **Barnacles**

Settlement of the barnacle, *Elminius modestus*, on spat collectors was light in 1974 compared with other years. Normally handled collectors exposed from mid-January to 19 February showed barnacle settlement densities between 0.15/cm^2 in the top half, to 0.75/cm^2 in the bottom half. Collectors exposed for longer periods showed moderate to heavy barnacle settlements (15 to 20/cm^2). Overturned collectors also showed moderate to heavy settlement, but collectors raised to higher level showed an even denser settlement rate; this was particularly true of collectors that were raised in March and April, which had a heavy settlement of >25 barnacles/cm^2 as well as a dense deposit of silt on the upper surfaces of the slats. GREENWAY (1969) has recorded denser barnacle settlement at higher levels in Huawai Bay.

(c) **Polyzoans**

A cheilostomatous polyzoan, *Watersipora cucullata*, was found to settle in isolated small groups (1 to 4 polypides each) in all collectors examined from March onwards, and was most numerous on middle layer slats of collectors overturned in March. It normally appears on the shaded surfaces of slats and grows over settled spat in the form of a thick mat.

DISCUSSION

Seasonal differences in intensity of rock oyster settlement may be attributed to variable environmental factors such as water temperature which affects spawning, whereas patterns of settlement are usually thought of as dependent on behavioral characteristics of larval oysters. The first major settlement of rock oysters occurred about the end of January in 1974 but settlement has varied from year to year; our observations (unpublished data) show that it took place in middle and late February in 1973, and after the middle of January in 1972. A second settlement maximum usually occurs in February or March, depending upon the timing and duration of spawning (DINAMANI, 1974a). However spatfalls have been observed as late as the end of April or early May in years when the first spawning has been delayed.

Observations on spawning, as indicated by plankton monitoring of oyster larvae, and on spatfalls, as recorded in commercial collectors, showed the following pattern: oyster larvae (80 - 150 μm in length) appeared in Huawai Bay during the 3rd week of December 1973, and were common up to the end of the month. Appreciable numbers (average 40 - 60 larvae/500*l* sample) were not found until after the middle of January. These observations checked well with spatfalls on trial collectors exposed from mid-December to mid-January, which showed only 3 spat/slat all <1.5 mm in size. Late stage larvae were found from the last week of January, and the first spat on our monitoring collectors were observed about the middle of February. Thus the evidence points to a major spatfall (settlement rate of *ca.* 0.250 spat/slat) during the first week of February. The length of larval life has been reckoned to be about 18 to 24 days (DINAMANI, 1973) at a temperature of 21 - 22° C.

From the end of February to the middle of March, no regular larval monitoring was possible in the Mahurangi area, but experimental collectors examined in the middle of March showed only a few spat of < 2 mm (about 12% of the total), and the mean number of spat/slat on these collectors was also lower than that of February. This probably meant that there were few larvae in the water and very little settlement occurred during that period. However, plankton samples taken from 18 March onwards revealed late-stage larvae, which suggested that a second peak in larval numbers probably occurred in March, and gave rise to a second spatfall. The large number of small spat observed in the collectors examined in April points to this.

Thus Mahurangi ordinarily has a long breeding season (GREENWAY, 1969), with probably two spatfall maxima from January to April. In the Australian rock oyster, THOMPSON (1950) recorded two maxima during the spring (November) and autumn (March). We have however no conclusive evidence of spring spawning in the New Zealand rock oyster (DINAMANI, 1974a).

Saccostrea glomerata larvae like those of many other species of oyster settle more heavily on lower than upper surfaces of collectors (NELSON, 1927; HOPKINS, 1935; SCHAEFER, 1937; COLE & KNIGHT-JONES, 1939; SIEBING, 1950; THOMPSON, 1950; MEDCOF, 1955). This characteristic is well demonstrated by our data for collectors that were experimentally overturned at various times in 1974 (Table 2, Figure 3), the subsequent settlement being largely confined to the 'new' lower surface. There was also a tendency at the beginning of the settlement season for the spat to settle in the bottom half of the collector bundle as demonstrated in data listed in Table 1. However towards the end of the settlement season, roughly equal numbers of spat are found in the top and bottom halves of the collector bundles. This was shown by the greater percentage of small-sized spat settling on the top half of the bundle after February. This may indicate a tendency, under natural conditions, for late-season settlement to occur higher in the intertidal zone than early season settlements.

There is also a tendency for the settlement to be almost exclusively on the lower surfaces early in the season, but to occur in small numbers (8 to 10% of the total) on the upper surfaces late in the season. This could be taken as evidence that oyster larvae avoid settling on lower surfaces that are already heavily populated by their own species. KNIGHT-JONES & STEVENSON (1951) and WISELY (1959) have observed that settling larvae tend to avoid surfaces where recently settled individuals of their own kind have attained a certain density. The term 'gregariousness' has been used to indicate the selection by settling larvae of surfaces associated with organisms of the same species, though, as pointed out by BAYNE (1969), it also "implies a response by the larvae to the previously settled individuals of the same species." This response could therefore either favour aggregation, or result in an avoidance reaction, depending upon the density of the individuals on a surface at any time. In the rock oyster the results of settlement on commercial collectors indicate that larvae probably begin to settle on upper surfaces of slats when spat densities on lower surfaces become high. In this type of collector, as the distance between the lower surface of one slat and an adjoining upper surface of another is only 12 mm, gregarious response could be a factor. In a series of experiments on the settlement of *Crassostrea virginica* (Gmelin, 1791), SHAW (1967) reported that more larvae settled on upper surfaces when slats were about 25 mm apart, but only on lower surfaces when the slats were 100 mm apart.

Analyses using 't-test' values for differences in mean spat density between normal and experimental collectors show significant values only for collectors overturned in February ($t = 2.147$, $P = 0.05$) and March ($t = 2.290$, $P = 0.05$), compared to normal collectors exposed for the same period. No significant differences were observed in mean spat density between normal collectors and raised collectors. However, it is obvious that in spite of increases in spat density in collectors overturned earlier in the season, spat sizes in these are generally smaller than in normal collectors (cf. Figures 2 and 3). This is also true of collectors raised to higher level. Therefore, reorientation of cultch material, either by overturning or raising during the spatting season, most probably affects spat growth. It remains to be seen whether the more even dispersion of spat on both surfaces of slats (a feature of overturned collectors) may, in later seasons, have the advantages of lesser overcrowding and hence better growth. This has to be weighed against the higher settlement rate of competitive species such as the Pacific oyster in the same collectors.

No obvious benefits, *e. g.*, higher survival of spat or abatement of barnacle settlement, were seen in collectors shifted to higher level. On the other hand, there were signs of higher silt deposition, which normally smothers small sized spat. Spat which settle later in the season generally have a poorer survival rate, as is evidenced here by the considerable drop in percentage of small size spat between April and May in normal collectors, as also in those overturned in April (see also GREENWAY, 1969).

CONCLUSIONS

1. Rock oyster commercial seed operations should preferably be initiated to coincide with the period of the first major spawning. This would ensure clean cultch surfaces for maximal settlement, better growth and survival of spat, with minimal fouling by organisms such as *Elminius modestus*, which have several spawning peaks and could settle at the same level. The extended oyster breeding season from January to March and the occurrence of at least two spawning maxima provide some safety factor for farming operations.

2. Plankton monitoring programmes which provide information on spawning activity and larval abundance might be of use to the seed industry, to enable the growers to catch the first set and to help them plan ahead. As pointed out by Loosanoff & Engle (1940), information on spawning time, intensity of setting and the probable rate of survival of spat under different conditions, would lead to better planned oyster farming. A monitoring programme was in fact tested during the 1975 season, and with refinement it may permit forecasts of dates and sizes of spatfall.

3. The study has also indicated that spatfall on the present type of collectors follows a seasonal pattern: initially spat settle almost exclusively on lower surfaces of slats, in the lower halves of bundles that are positioned close to MLWN; as the season progresses, spat may settle on both upper and lower surfaces of collector slats, in both top and bottom halves of collector bundles, and at higher levels in the intertidal zone than at the beginning of the spatfall season. Thus, at the end of a good season all slats in the bundle have a somewhat even distribution of spat.

4. The study also reveals that spat which settle early in the season survive better and are larger at the end of the season than spat which settle later in the season. It may therefore be worthwhile to maintain a monitoring programme of planktonic populations of oyster larvae to forecast the first sets of the year.

5. The study shows that turning collectors up-side-down during the early part of the spatting season may increase their catch of spat: *e. g.*, collectors overturned in February took 37% more spat than normally handled (unturned) collectors, and collectors overturned in March took 17% more spat. In both cases, however, the increase counts were largely due to the greater number of small-sized late-settling spat. In contrast, the overturned collectors have fewer spat of sizes over 10mm compared to the normal collector.

6. Another factor is the possibility of settlement of other organisms such as the Pacific oyster on the 'new' surface; collectors overturned in February had more than double the number of Pacific oysters of normal collectors, and collectors overturned in March had more polypides of *Watersipora*. The incidence of other competitive species and the time of their settlement may have a marked effect on rock oyster spat, particularly their growth.

7. In good breeding seasons, with at least two spatfalls between January and March, normal settlement patterns provide adequate spat densities and growth in commercial type collectors. Whether there is need for special handling of collectors is an open question.

SUMMARY

Settlement of the New Zealand rock oyster, *Saccostrea glomerata* (Gould) [= *Crassostrea glomerata* (Gould)] on bundles of slat-type commercial collectors in the Mahurangi estuary in New Zealand, showed two peaks of spatfall between January and March 1974 in a definite pattern: the first sets were predominantly on the lower surface of slats and on the lower layers of slats in the bundles. As the season progressed sets were still largely on lower surfaces but spread more uniformly through the several layers of collector slats. By overturning the bundles at intervals during the season, significantly higher ($P = 0.05$) mean density of spat was obtained if carried out in the earlier part of the season, but brought about a reduction in maximum spat size, and also a greater settlementment of competitive species such as the Pacific oyster. Moving collectors at intervals to higher tidal level did not affect spatfall appreciably but increased silting on collector surfaces.

ACKNOWLEDGMENTS

We are grateful to Dr Carl Medcof, St. Andrews, Canada, for his valuable suggestions and criticism, and to Messrs G. Duncan Waugh and Carel Vooren of the Fisheries Research Division, New Zealand, for helpful comments on the typescript.

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